

Testing efficient luminaires and LED retrofit lamps – experiences from Switzerland

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Abstract

Luminaires play a role when it comes to generating energy-efficient light. Efficient light bulbs are promoted for homes today, but consumers don't get any information about domestic luminaires and how efficient they are. To close this gap, a test method for domestic luminaires was developed in Switzerland. Experiences from the past three years show that retailers and manufacturers are considerably interested in such information. The main benefits are firstly to gain information for buyers and customer service, secondly to get product data from independent measurements.

With this article we intend to give clues and motivation to retailers on how to communicate efficiency and quality of domestic luminaires to their customers. The relevant parameters are named. Measurements of more than 150 products show in what range the good products are. Topten¹ evaluates the best products and presents them online. Energy savings can be determined compared to typical luminaires that have been measured as a reference. Examples are shown how retailers use the test results to promote these efficient luminaires to their customers.

One chapter is dedicated to a test of 14 LED retrofit lamps that was made in Switzerland in the end of 2010. Since the LED retrofit lamp market is expanding rapidly, it is important to know the quality of these new products. The test results show that many LED retrofit lamps are of high quality and efficiency, and also identifies the critical parameters.

Introduction: Swiss tests of domestic luminaires and LED retrofit lamps

Today, consumers don't get any information about the efficiency of a domestic luminaire they intend to buy. The focus is on the light bulbs, for many of which an energy label is mandatory (excluded are spot lamps). However, the luminous efficacy of the lamp does not tell how much light is actually coming out of the luminaire.

To close this gap, Topten¹ and the University of Applied Sciences HTW Chur developed a test method for domestic luminaires in Switzerland. The goal was to obtain the significant specifications for efficiency and quality with an easy, practical and therefore cost-effective procedure. The domestic luminaires are sent for testing by two large swiss retailers as well as other retailers and specialist shops. Since the opening of the laboratory in 2008, over 150 domestic luminaires have been tested.

With LED retrofit lamps, a new technology for replacing incandescent and halogen lamps is coming to the market. The product range is expanding rapidly and it is important to know the quality of these new products. An interesting product test was made by the Swiss Agency for Efficient Energy Use S.A.F.E. in the end of 2010 and we dedicate a chapter of this article to it.

¹ Topten is a consumer-oriented online search tool, which presents the best appliances in various categories of products. The key criteria are energy efficiency, impact on the environment, health and quality. As a communication tool it helps to show how our energy consumption causes climate change and what we can do personally to reduce our impact. It is also a powerful instrument to influence manufacturers. Topten was launched in 2000 in Switzerland. Since then, sixteen European national Topten sites have been established, as well as sites for USA and China. See www.topten.eu

Important parameters: knowing the efficiency and quality of luminaires

For judging how efficient a luminaire is, one must know how much electric energy is used and how much light is coming out of the luminaire. There are two approaches to determine how much light is given by a luminaire: Either measuring all the light coming out of the luminaire (luminous flux) or measuring how bright the user surface is being lit (intensity of illumination). These parameters must be determined:

- energy consumption during use and standby
- luminous flux (lumen) or intensity of illumination on the use surface (lux or lx)

For judging the quality of LED luminaires, the color rendering index CRI and color temperature (kelvin) are determined in the test method mentioned in this article.

Energy consumption

The data for energy consumption during use and standby can be used to estimate the annual energy consumption of the luminaire in kWh per year. We suggest that 760 hours use and 8000 hours standby are a reasonable and realistic usage pattern (according to Topten and the University of Applied Sciences HTW Chur).

Example: energy consumption of a table luminaire (LED)

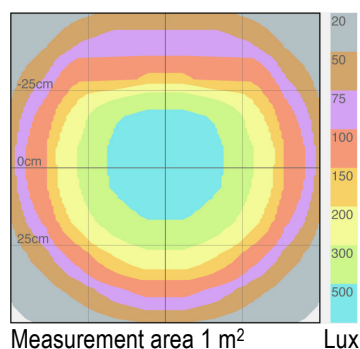
Energy consumption during use: 10W
Energy consumption during standby: 0.4W
Estimate for annual energy consumption:
 $(760\text{h/year} * 10\text{W} + 8000\text{h/year} * 0.4\text{W}) / 1000\text{kW/W} = 11 \text{ kWh/year}$



Luminous flux and intensity of illumination

The luminous flux in lumen describes the total amount of light which is emitted from a light source into the room. It is most commonly measured in a goniometer, a rather expensive apparatus. Topten and the University of Applied Sciences HTW Chur aimed for a more cost-effective procedure. A new light laboratory has been installed that allows determining how bright a surface is lit, therefore measuring the intensity of illumination on the user surface (in lux) instead of the luminous flux. First experiences with this method of luminaire testing could be gained in cooperation with several Swiss retailers.

In a standardized room (3 x 3 x 2.4 meters), a robot measures the intensity of illumination (lux) at 100 spots on the ground surface. This measurement gives a very good indication of the light that can be used on work tables or dining tables for examples. There are other types of luminaires which are meant to illuminate rather a room than a surface. To take into account the light that is emitted all around, the paint on walls and ceiling has defined degrees of reflection. The ground surface is illuminated indirectly by the light reflecting from walls and ceiling. For each type of luminaire the height of the light source as well as the size of the use surface was defined based on the typical usage.



Example: distribution and average intensity of illumination on measurement surface (same table luminaire as above)

Average intensity of illumination on measurement area:
174 lux

Maximum intensity of illumination: 775 lux

Area illuminated stronger than 500 Lux: 0.11 m²

Energy efficiency

With the described measurements the energy efficiency is determined in kWh per year and per 100lx average intensity of illumination on measurement area. For the table luminaire in the examples above it is 6 kWh/year/100lx.

Color rendering index

The color rendering index (CRI) informs about the quality of the light compared to daylight. Especially for LED, where there are very big differences, it is important to inform the buyers about the color rendering index.

- Daylight: 100
- Incandescent and halogen lights: 100
- Energy saving lamps: 80
- LED: 50 to 95

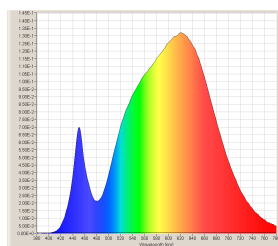
Color temperature

The color temperature indicates if the light is slightly blue or red. Slightly red light is called warm white, whereas slightly blue light is referred to as cold or daylight white. In between is the so-called neutral white. It is measured in kelvin.

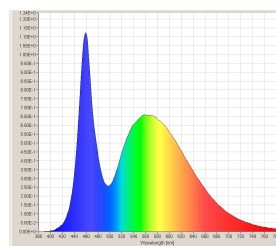
- Warm white: 2700 to 3500 kelvin (incandescent lamps 2700 kelvin, halogen 3000 kelvin)
- Neutral white: 3500 to 5000 kelvin
- Cold or daylight white: 5000 to 10000 kelvin (daylight 6500 kelvin)

All incandescent and halogen lights are warm white. Fluorescent lamps (FLs) and LED lights exist with a broad range of color temperatures. LEDs get more efficient with higher color temperature. Therefore LED luminaires often have cold white light. In Switzerland (and possibly other countries in Europe) people prefer warm white lights though. This has led to disappointment with LED luminaires in the past. It is therefore important to inform buyers about the color temperature.

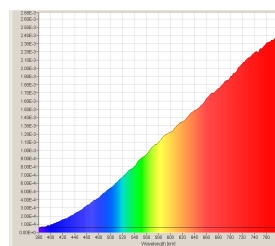
Examples of color spectres:



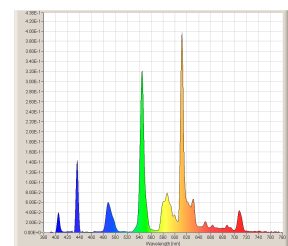
Warm white LED



Cold white LED



Halogen lamp



Energy saving lamp

Topten: Choice of the best luminaires

Several Swiss retailers send domestic luminaires for testing at the University of Applied Sciences HTW Chur. They receive for each luminaire a detailed protocol of the measurement. In addition, the luminaires are evaluated and the best ones are labeled by Topten Switzerland and presented online. Luminaires that fulfill the criteria defined by Topten Switzerland (see below) are published on the Internet (www.topten.ch). In order to create more publicity for these efficient luminaires, Topten Switzerland supports the retailers with the labeling and promotes articles in different media (customer magazines or trade journals).

Example: Screenshot of the best luminaires for dining tables on www.topten.ch (in German)
 The table contains the following information: retailer, name of product, purchase price, electricity costs in 15 years, energy efficiency (kWh/year/100lx), part of energy used in standby, dimmability, lamp type, color temperature.

	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Anbieter	Micasa	Micasa	Lumimart	Micasa	Micasa	Lumimart
Modell	Cut LED	Shine	Led's go	Led's go XXL	Seattle	Gamma
Kaufpreis (Fr.)	569	699	699	599	599	499
Stromkosten (Fr. in 15 J.)	59	60	66	68	51	41
Energieeffizienz (kWh/a/100lx)	5	5	5	5	6	7
Anteil Standby (%)	0%	0%	0%	0%	0%	0%
Lichtregelung	nicht dimmbar	nicht dimmbar	nicht dimmbar	nicht dimmbar	nicht dimmbar	nicht dimmbar
Lampenbestückung	LED	LED	LED 7 x 3.5W	LED	LED 5 x 3W	LED 6 x 3W
Farbtemperatur	warmweiss	warmweiss	warmweiss	warmweiss	warmweiss	warmweiss

Criteria: So what is a good luminaire (according to Topten Switzerland)?

After having measured over 100 luminaires, Topten Switzerland set the following benchmarks regarding efficiency:

- 8 kWh/year/100lx for spots and table luminaires (measured on an area of 1 m² at 0.5 m height)
- 8 kWh/year/100lx for luminaires for dining tables (measured on an area of 1 m² at 0.75 m height)
- 32 kWh/year/100lx for luminaires installed on the ceiling and freestanding lamps (area of 9 m²)
- 50 kWh/year/100lx for luminaires installed on the wall at 1.7 m height (area of 9 m²)




In addition, Topten Switzerland demands the following qualities:

- the supplier or manufacturer must have ISO certification (series 9000 and ideally 14000)
- conventional ballasts are not accepted, only electronic ballasts
- energy consumption during standby max. 1 watt
- color rendering index CRI min. 80
- LED luminaires must have a color temperature below 3500 kelvin
- luminaires for reading must get 500 lux on an area of an A4 paper sheet (0.07 m²)
- luminaires for work tables must get 500 lux on an area of an A3 paper sheet (0.13 m²)




Efficient luminaires and how much energy they save

Here examples are shown for the two most popular luminaire types. For more examples, see the website www.topten.ch (German, French, Italian).

Product comparison 1: Typical vs. efficient freestanding lamps. The energy saving in 15 years is about 2000 kWh.

			
	Typical freestanding lamp	Topten luminaire example 1	Topten luminaire example 2
Lamp type	Eco halogen R7s 230W	Fluorescent T5 2GX13 40W	Energy saving lamps E27 3x20W
Average intensity of illumination on 9m ²	132 lux	119 lux	166 lux
Energy consumption	225W	39W	51W
Consumption per year	171 kWh	30 kWh	39 kWh
Efficiency	130 kWh/year/100lux	25 kWh/year/100lux	23 kWh/year/100lux
Saving in 15 years	-	2115 kWh	1980 kWh

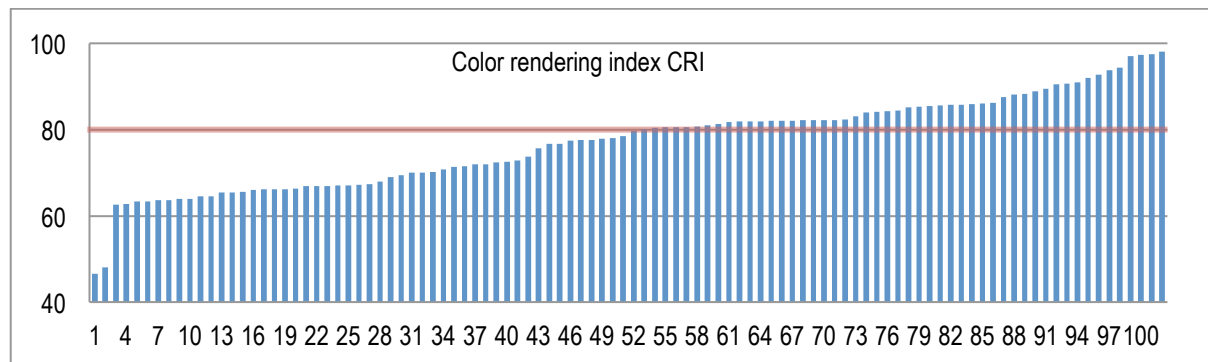
Product comparison 2: Typical vs. efficient spots. The energy saving in 15 years is about 420 kWh.

			
	Typical spot	Topten spot example 1	Topten spot example 2
Lamp type	Halogen 50W	LED 5W	LED 3W
Average intensity of illumination on 1m ²	105 lux	124 lux	46 lux
Energy consumption	44W	6.5W	4.4W
Consumption per year	33 kWh	5 kWh	3 kWh
Efficiency	32 kWh/year/100lux	4 kWh/year/100lux	7 kWh/year/100lux
Saving in 15 years	-	420 kWh	450 kWh

LED and color rendering index CRI

The color rendering index CRI varies greatly with LED luminaires and should be paid attention to. Experiences from Switzerland indicate that every second LED luminaire model may have an unsatisfying CRI below 80. See figure on next page.

Color rendering index CRI of 102 LED luminaires which were measured in the light laboratory. Only half of them (53) have a CRI above 80. Every third (30) has a CRI even below 70.



Partnerships with retailers

Several retailers in Switzerland use Topten as a label to promote these efficient luminaires to their customers (e.g. labeling at point of sale, print materials...). Procurement managers of the retailers ask increasingly for Topten requirements when selecting luminaires. They welcome guidance on specifications for efficiency and quality.

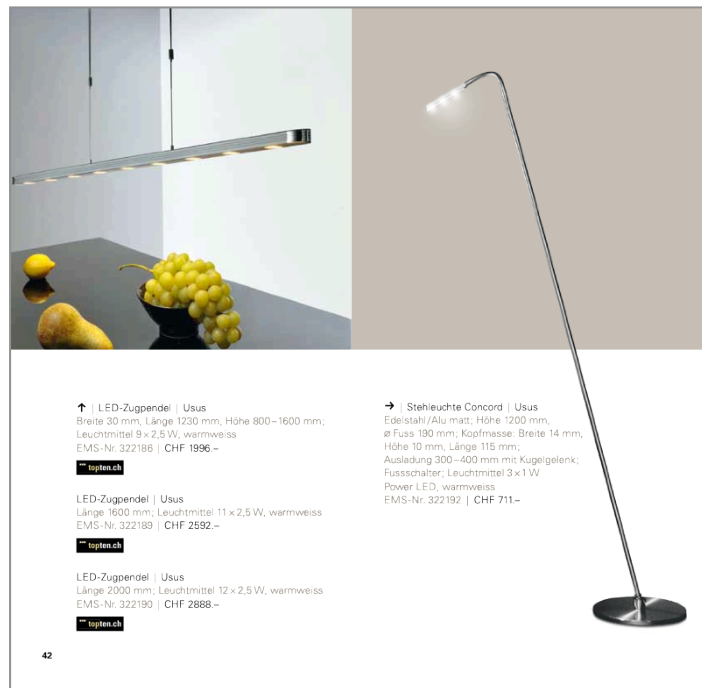
Example 1: The view of a retailer. The Category Field Manager Lighting of a retailer explains why they send luminaires for testing to the University of Applied Sciences HTW Chur.

One reason is customer service. The intensity of illumination on the use surface is important information for the customers as well as the luminous flux. It is used to classify the assortment of luminaires into decoration, use at home and use at the work place. Another reason is the independent measurement of photometrical and electrical parameters. Especially with LED, product data is sometimes imprecise.


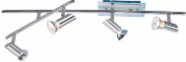



This specific retailer uses the test results in Flyers for customers and sales staff as a support for selling (see picture below). The test reports are all available on the Intranet for the sales staff as well. It is planned to declare the average intensity of illumination on the product label. If a product fulfills the Topten criteria, this will also be indicated on the product label. These actions are communicated in customer magazines and other media. The retailer can demonstrate that they value efficient use of energy and take the role as a trailblazer.

Hängeleuchte, LED, Nickel matt, Glas, höhenverstellbar 100 - 150 cm	Hängeleuchte, LED, Nickel matt, Glas, höhenverstellbar 90 - 145 cm	Tischleuchte, LED, Aluminium, 4-Stufen Dimmer	Tischleuchte, LED, Aluminium, 4-Stufen Dimmer
Breite 95 cm 4201.378 5x3 W RICHMOND inkl. vRG 429,-	Breite 100 cm 4201.441 5x4 W SHINE inkl. vRG 699,-	Höhe max. 91 cm 4202.649 5,4 W Z BAR inkl. vRG 299,-	Höhe max. 91 cm 4202.748 5,4 W Z BAR inkl. vRG 299,-

Example 2: How Topten is used as a label in the shop and in the catalogue



Domestic luminaires: Types and market

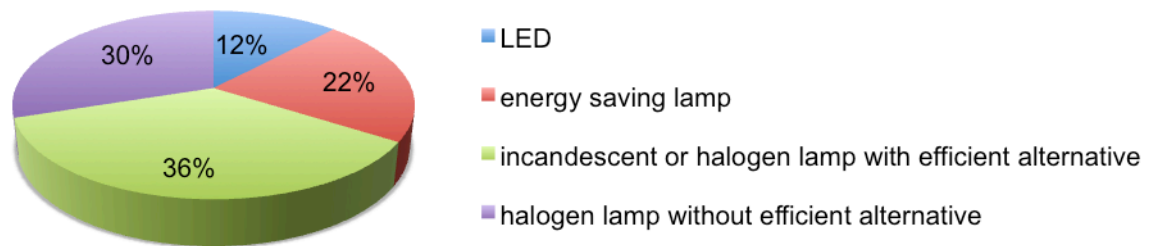
				
Freestanding lamp	Spots	Suspension	Ceiling/Wall	Table
Common lamp types:				
bulb (E27), halogen stick (R7s)	halogen spot (GU10, GX3.5)	bulb (E27), halogen pin (G9)	bulb (E27), FL tube T5 (G5)	bulb (E27)

The most common sold luminaire type is the freestanding lamp, followed by spots, then luminaires for suspension, ceiling/wall and table. Next to these examples, there are many different designs and many purposes (decoration, furniture in-built, garden / outside).

Typically, a model may stay on the market for 3-5 years, a fashion model 1-2 years. Only few classics are sold over many years. In recent years, more and more LED products are appearing in the assortments. The figure below shows that LED luminaires can make over 10% of the products range. In Switzerland, LED products are possibly advancing faster into the market than in other countries.

2 million domestic luminaires are sold annually in Switzerland. The total market without light sources is 100 million Euros [1]. The professional market in comparison amounts to 300 million Euros per year, by guess this is 2 million sold units as well.

Domestic luminaires of a big Swiss retailer by light sources (assortment 2010) [1]

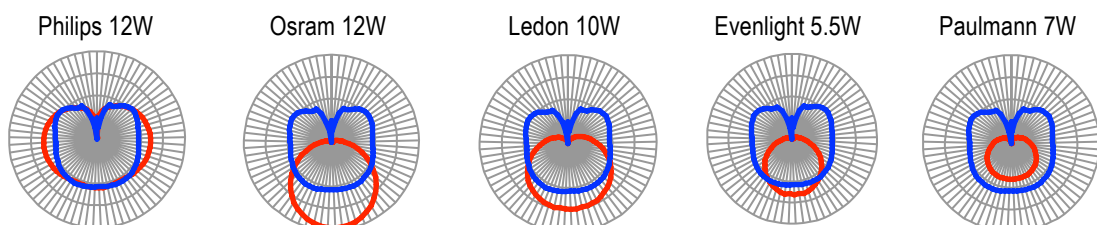


If one is dissatisfied with the color temperature or amount of light emitted from a luminaire, it can partially be adjusted by exchanging the light bulbs. This works for luminaires with CFLs, halogen or incandescent lamps. FLs mostly cannot be replaced with a higher or lower wattage. LED luminaires generally contain integrated, non-exchangeable light sources. However, there's a rapidly growing choice of LED retrofit lamps that fit into the most common sockets like E27, E14, GU10, GX3.5.

New technology: LED retrofit lamps in the test

Since the LED retrofit lamp market is expanding rapidly, it is important to know the quality of these new products. For this purpose, S.A.F.E. tested 14 LED retrofit lamps in the end of 2010 (link to Swiss television show about this test see [2]; an english summary of the test results is available for PDF download on www.topten.eu). The main results of this test are:

1. High Efficiency: Most tested lamps are as efficient or better than compact fluorescent lamps (about 60 lm/W). The best LED retrofit lamp in the test had 94 lm/w, the weakest 34 lm/W.
2. There are many LED retrofit lamps that can replace an incandescent lamp with 20 - 30 watts, comparing the light flux (lumen). In the test were also three lamps that can even replace an incandescent lamp with 60 watts.
3. Some manufacturers give imprecise product information. Notedly when it comes to the replacement of incandescent lamps, as sometimes LED products with 20 – 50% lower light flux are recommended as replacement.
4. Good light quality: All tested lamps have warm white light (2600 – 3500 kelvin) and usually a good color rendering index (over 80, max. 92). However the CRI needs attention: four tested lamps had a color rendering index of only 55 – 68.
5. Only one of the tested LED retrofit lamps matched an incandescent lamp (blue line) in its light distribution (Philips 12W). All other products resemble rather a spot's light distribution with little light to the back and side.



Examples: The 3 best and the 2 worst LED retrofit lamps in the test

		Philips 12W	Osram 12W	Ledon 10W	Evenlight 5.5W	Paulmann 7W	Incandescent 60W
							
Consumption	W	12.8	13.5	9.4	5.7	5.7	60.0
Light flux	lm	823	909	589	331	194	700
Efficiency	lm/W	64	68	63	58	34	12
Replacement (real)	W	61	66	47	31	20	60
Replacement (Info)	W	50	60	60	50	-	-
Color temperature	K	2670	2722	2710	3415	2516	2700
CRI	-	81	86	92	66	78	100
Dimmable		Yes	No	Yes	No	Yes	Yes
Proportion of light back/side/front		14/61/25	0/38/62	2/16/82	0/27/73	0/34/66	16/52/32

Standards and regulations relevant for domestic luminaires

Standards

EN 13032-1: Light and lighting - Measurement and presentation of photometric data of lamps and luminaires - Part 1: Measurement and file format.

EN 12464-1: Light and lighting - Lighting of work places - Part 1: Indoor work places. (This standard contains criteria for limiting glare).

Annex III of Commission Regulation (EC) No 244/2009 of 18 March 2009 names further standards for the testing of lamps.

Requirements

Commission Regulation (EC) No 244/2009 of 18 March 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for non-directional household lamps.

Commission Regulation (EC) No 859/2009 of 18 September 2009 amending Regulation (EC) No 244/2009 as regards the ecodesign requirements on ultraviolet radiation of non-directional household lamps.

Commission Regulation (EC) No 245/2009 of 18 March 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for fluorescent lamps without integrated ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps, and repealing Directive 2000/55/EC of the European Parliament and of the Council.

- Excluded from these European requirements are directional lamps.
- There are no efficiency requirements for luminaires.
- In 2011, the European Commission possibly presents first drafts for a directive with implementing measures for directional lighting: a first working document on halogens and LEDs is awaited. A legislation on luminaires or 'lighting design' could also be proposed.

Labeling

Commission Directive 98/11/EC of 27 January 1998 implementing Council Directive 92/75/EEC with regard to energy labelling of household lamps.

- Excluded from this European directive are lamps with an input power of less than 4 watts and reflector lamps.
- There is no mandatory labeling regarding consumption and efficiency for luminaires.

In Switzerland there are two voluntary labels:

- For professional luminaires: MINERGIE® Label [3]
- For domestic luminaires: Topten

Discussion and prospects

Together with retailers, Topten and the University of Applied Sciences HTW Chur have taken a step and focus not only on the lamp, but look at how much light is actually coming out of a luminaire. Experiences from the past three years show that retailers and manufacturers are considerably interested in such information. The main benefits are firstly to gain information for buyers and customer service, secondly to get product data from independent measurements. With this article we hope to give clues and motivation to retailers on how to communicate efficiency and quality of domestic luminaires to their customers.

A test method and the declaration of efficiency for domestic luminaires should be regulated on a European level. Taking into consideration the characteristics of domestic luminaires, the test method should be simple and affordable. This article describes a first example of a measurement that gives relevant data in a simple way. A measurement in a goniometer would be desirable. It delivers data on the luminous flux that is easy to compare between all types of luminaires.

The following essential data should be available:

- energy consumption during use and standby
- luminous flux (lumen) or intensity of illumination on the use surface (lux)
- for luminaires with in-built LEDs: CRI and color temperature

We propose the following requirements for domestic luminaires:

- Standby consumption should be limited to 1 watt for luminaires with sensors or ballasts for dimming (in a second step to 0.5 watt). For luminaires without sensors or that are not dimmable, no standby consumption should be allowed.
- Luminaires for work tables and reading should be required to get 500 lux on an area of at least 0.13 m² or 0.07 m², respectively.
- For LED products, a CRI of minimum 80 should be mandatory.

Acknowledgements

The Topten project team gratefully acknowledges the financial support of:

- The European Commission's Intelligent Energy Europe Programme (<http://ec.europa.eu/energy/intelligent/>) which made it possible for Topten to be present in 16 European countries and continues to support the build-up in two more European countries (www.topten.eu).
- The European Climate Foundation (www.europeanclimate.org) who supports Topten in updating and expanding technical and policy analysis of the most energy-efficient products.
- WWF (www.wwf.org) who supports the build-up of Topten China (www.top10.cn) and supports other Topten projects in Hongkong, the USA (www.toptenusa.org) and Europe.
- The Swiss government: REPIC (Renewable Energy & Energy Efficiency Promotion in International Co-operation - www.repic.ch) and SECO (State Secretariat for Economic Affairs - www.seco.admin.ch) who supports the build-up of Topten China.

References

[1] Indications from retailers

[2] Test of 14 LED Retrofit Lamps - English Summary of Test Results. PDF download at:
http://www.topten.eu/english/criteria/selection_criteria_energy_saving_lamps.html&fromid=

Link to Swiss television show on the 01/11/2011 about the test of 14 LED retrofit lamps (in Swiss German): <http://www.kassensturz.sf.tv/Nachrichten/Archiv/2011/01/11/Test/Was-die-neuen-LED-Lampen-taugen>

[3] Complete list of professional luminaires with the Swiss MINERGIE® label, requirements and verification procedure (in German): <http://www.toplicht.ch/>

English information about MINERGIE®: http://www.minergie.ch/home_en.html